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THE COMPLETE FISSURES OF THE HUMAN CEREBRUM, AND THEIR SIGNIFICANCE IN CONNECTION WITH THE GROWTH OF THE HEMISPHERE AND THE APPEARANCE OF THE OCCIPITAL LOBE.

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THE complete fissures of the cerebral mantle (the *Totalfalten* of His) appear at an early period in the development of the hemispheres. They are distinguished by the fact that they are the result of a series of deep infoldings of the thin cerebral wall. On the surface of the hemisphere they present a sharply-cut linear appearance. The walls of the different folds are, as a rule, closely applied to each other, and they constitute deep shelf-like projections into the cavity of the primitive lateral ventricle.

The study of these infoldings is a matter of extreme difficulty, because by far the greater number have only a temporary existence. As cerebral growth advances they are obliterated, and the hemisphere surface again becomes smooth. Several, however, occupy positions which later on are occupied by permanent furrows, and either show a direct continuity of existence with these, or at least act as their precursors. It is not surprising, therefore, that very different opinions should be expressed regarding the fate of those primitive infoldings which present this relation to the permanent furrows. More especially do we find the calcarine and parieto-occipital fissures the subject of contending views.

[1] This paper contains the substance of one chapter of a memoir at present in course of preparation, and which will shortly be published by the Royal Irish Academy as "Cunningham Memoir, No. 6: A Contribution to the Anatomy of the Cerebral Hemispheres."

Amongst the "Totalfalten," His[1] includes the fossa Sylvii, but Mihalkovics[2] rightly denies it a place in this category. The projection into the hemisphere cavity which corresponds with it (viz., the corpus striatum) is not formed by an infolding of the mantle wall, but as an elevation on the floor of the prosencephalon. The surface area corresponding to this internal projection does not keep pace with the mantle as the latter grows around it, and in consequence the Sylvian depression makes its appearance.

It is very questionable if, under ordinary circumstances, any of the complete fissures which appear on the outer face of the embryonic hemisphere are retained as permanent sulci. Later on we shall have occasion to mention two which persist in the Ape, but the corresponding fissures in Man are apparently, as a rule, of a transitory nature.

On the inner or mesial face of the hemisphere, on the other hand, two, or it may be three, of the complete fissures are retained. The conditions of growth here are different. These are more favourable to the appearance of such infoldings, and also more favourable to their retention.

Fissura Arcuata.—Towards the end of the second month of intra-uterine life the fissura arcuata (*Bogenfurche* of Arnold, or *Ammonsfurche* of Mihalkovics) makes its appearance. It pursues a curved course, and cuts off the lower part of the mesial surface of the hemisphere in the form of a semicircular part, which receives the name of arcus marginalis (*Randbogen* of Schmidt). In front the fissura arcuata extends into the frontal region, whilst behind it is carried round towards the extremity of the temporo-sphenoidal lobe. It is in connection with the arcus marginalis or "Randbogen" that the fornix, anterior commissure, corpus callosum, and the septum lucidum are formed. Behind the splenium of the corpus callosum the corresponding part of the arcus marginalis is converted into the gyrus dentatus and the uncus hippocampi. The hind part of the primitive fissura arcuata, which bounds the arcus marginalis, is retained as the hippocampal fissure, and gives rise to the elevation in the floor of the lateral ventricle, which is known

[1] *Unsere Körperform*, Neunter Brief, p. 116.
[2] *Entwicklungsgeschichte des Gehirns*, 1877.

as the hippocampus major. The fore part of the same fissure is said to be retained as the callosal fissure.

The facts stated above regarding the fissura arcuata are well known, and have been carefully and faithfully described by several embryologists. It would appear, however, that the fissure does not always present the simple condition which we have noted. His, who maintains that the inner face of the cerebrum is at no time completely smooth and devoid of furrows, figures the fissura arcuata in a ten weeks' fœtus,[1] and he represents its hinder end rising upon the mesial face of the hemisphere until it ultimately reaches the upper border. Turning round this, it is continued downwards on the outer surface of the back part of the cerebral mantle. Mihalkovics,[2] commenting upon this, denies that the fissura arcuata, in well-hardened brains ever extends upwards to the free border of the hemisphere.

In a brain in my possession, apparently about the end of the fourth month, or perhaps a week later, an interesting condition of the fissura arcuata is present (fig. 2, No. 2, p. 318). In this specimen there is not a trace of the corpus callosum, but the fornix is fully formed in connection with the lower edge of the arcus marginalis, although the two sides have not yet adhered to form the central body-part. The fissura arcuata is in two separate portions—a hinder part corresponding in position with the future hippocampal fissure (H.), and a short anterior part (F.A.). This anterior part lies nearer the front than the back end of the cerebrum, and is situated so high up on the mesial surface of the hemisphere that, at first sight, it might be taken for a precursor of the calloso-marginal sulcus. The same condition was present in both hemispheres. On removing the roof of the cerebral vesicle, the fold corresponding to this fissure was seen to project horizontally outwards like a shelf across the greater part of the width of the primitive ventricle (fig. 2, No. 4, p. 318). Its depth may be appreciated by examining the figure, which represents a transverse microscopic section through the fold, as seen under a low power (fig. 3, D., p. 319).

This detachment of the anterior part of the fissura arcuata from the posterior hippocampal portion, its reduction in length,

[1] His, *Unsere Körperform*, Leipzig, 1875, p. 113, fig. 112.

[2] Mihalkovics, *Entwicklungsgeschichte des Gehirns*, Leipzig, 1877, p. 158.

and the similarity which it presents to temporary infoldings in the course of their obliteration, leads me to suppose that in certain cases the posterior hippocampal part of the fissura arcuata alone is retained; or, in other words, that the front part is wiped out, and that the callosal sulcus of the fully-formed brain is a new fissure, which is called into existence at the time when the callosal fibres cross from one hemisphere to the other. To me it is quite unintelligible how His can possibly represent the fornix as being the inner projection arising from the infolding which corresponds to the front part of the fissura arcuata.[1]

Certain observers speak very decidedly upon the identity between the front part of the fissura arcuata—(*Bogenfurche*)—and the callosal sulcus. Schwalbe remarks:—"The 'Bogenfurche,' in its upper part, becomes the upper boundary of the corpus callosum."[2] Schmidt[3] gives expression to a similar view. Were it not for this, I should be inclined to believe that the fore part of the fissura arcuata is obliterated in every case. Unfortunately, Mihalkovics makes no definite statement upon this point, although his drawings would seem to favour a similar conclusion.[4] Thus in pl. iii. he depicts two brains in which the corpus callosum has not reached its full development, and in these the "Bogenfurche" is represented as fading away on the mesial face of the hemisphere, a short distance above the hinder end of that structure.

The calcarine and parieto-occipital fissures would naturally fall to be considered at this stage, but their origin is so closely connected with the appearance of the transitory fissures, that it is more convenient to defer their examination until the latter have been dealt with.

Transitory Fissures (*Vorübergehenden Rinnen* of Schwalbe; *Temporären Furchen* of Ecker; *Vergänglichen Furchen* of Mihalkovics).—These are a series of fissures which appear at an early period upon the cerebral hemisphere in connection with deep infoldings of its thin wall. They are further distinguished by their transitory character. After existing for a period of about two months or more on the mesial wall, and for about two-thirds of that time on the outer wall of the cerebrum, they are, for the most part, finally completely obliterated, and the hemisphere surface becomes smooth. When we come to study

[1] *Unsere Körperform*, Neunter Brief, p. 116.

[2] *Lehrbuch der Neurologie*, p. 256.

[3] "Beiträge zur Entwicklungsgeschichte des Gehirns," *Zeitsch. f. Wiss. Zool.*, 1862, Bd. xii. pp. 54, 55.

[4] *Entwicklungsgeschichte des Gehirns*, vide pl. iii. figs. 24, 25.

the influences at work in their production, we shall see that they constitute a most suggestive and interesting chapter in the developmental history of the human brain.

It is to J. F. Meckel that the credit is due of having, in the first instance, recognised these transitory fissures. In 1815 he published a paper in which he remarks:[1]—"Although I find the brain in the six to the seven weeks' embryo completely smooth, the very thin walls of the lateral ventricles appear to shape themselves into extremely numerous and deep convolutions and furrows from the eighth to the ninth week." He asserts that the fissures are due to deep infoldings of the hemisphere wall, and is at considerable pains to prove that the condition is not produced by the shrinkage brought about by the hardening reagent. He therefore holds "that these convolutions are primitive formations, and are essentially a part of the development of the brain." His account of the manner in which these early infoldings of the hemisphere wall disappear is of some interest. We shall use his own words:—"But upon this period another supervenes in which these convolutions, as well as their outer and inner surfaces, grow into each other, so that the surface of the brain, both inside and outside, again becomes smooth." And he considers that this process of obliteration may be regarded as affording a means by which the wall of the ventricle is thickened, and also by which the white substance is increased in quantity.

In the following year (1816) Friedrich Tiedemann[2] also refers to these primitive transitory furrows, but he falls into the error of supposing that they represent the earlier conditions of the permanent sulci.

Schmidt[3] in 1862 figured them for the first time, and he clearly recognised their temporary nature. One point of importance, he adds, viz., that although he has failed to discover them in the embryos of the Sheep, Ox, and Pig, he believes that he has seen faint traces of them in the brain of the early Cat embryo.

Ecker,[4] His,[5] and Mihalkovics,[6] and other German authors have likewise taken notice of the temporary furrows, although they have, as a rule, dealt with them briefly, and have not made a serious attempt to unravel the part which they play in the process of brain development. It is but right to mention, however, that Richter[7] has

[1] *Deutsches Archiv f. Physiol.*, Halle and Berlin, Bd. i. 1815.

[2] *Anatomie und Bildungsgeschichte des Gehirn im Fœtus des Menschen*, Nürnberg, 1816.

[3] "Beiträge zur Entwicklungsgeschichte des Gehirns," *Zeitsch. f. Wiss. Zool.*, Bd. xi.

[4] "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirnhemisphären im Fœtus des Menschen," *Archiv f. Anthrop.*, Dritter Band, Drittes und Viertes Heft, 1869.

[5] *Unsere Körperform*, Leipzig, 1875.

[6] *Entwicklungsgeschichte des Gehirns*, 1877.

[7] "Ueber die Entstehung der Grosshirnwindungen," *Virchow's Archiv*, Berlin, 1887.

given a very admirable account of the fissures in question, and has added considerably to our knowledge regarding them.

It is somewhat curious that Bischoff, writing as late as 1868, should have cast doubts upon the reality of the transitory furrows. He asserts that all previous observations in this direction are founded upon an error, and that the fissures in question are produced artificially by the action of the alcohol in which the brains have been immersed. He further maintains that in specimens treated with chloride of zinc the surface of the hemisphere remains perfectly smooth up to the time of the appearance of the permanent sulci. Ecker disposes of this objection by the statement that he has observed the transitory furrows in the brain of a third-month embryo which was examined in the fresh condition.

In Italy Giacomini,[1] Romiti,[2] and Mingazzini[3] have paid some attention to the temporary fissures, but in this country little or no notice has been taken of them. It is true that Callender in his "Lectures upon the formation and early growth of the Brain of Man,"[4] has referred to them, but his systematic neglect of the work done by others in the same field greatly diminishes the value of his observations.

The material which I have had at my disposal for observing the characters and tracing the history of the temporary fissures has not been so abundant as I might have desired. I only possess the brains of three embryos which come within the limits of the prescribed period, viz., one a little over the third month, and two which I take to be slightly over the fourth month. But in addition to these I have been allowed in the most generous manner to handle, describe, and photograph four very characteristic specimens in the museum of the University College of London. These range from the middle of the third month up to near the end of the fourth month or thereabouts. Further, Professor Victor Horsley has been so kind as to furnish me with a beautiful series of photographs of the fœtal brain preparations which are displayed in the museum of the University of Oxford. One of these from an embryo approaching the fourth month is especially characteristic (fig. 5, Nos. 4 and 5, p. 322). The figures which are given by Schmidt, v. Kölliker, and

[1] *Guida allo studio delle circonvoluzioni cerebrali dell' uomo*, Torino, 1884.

[2] "Sull' ordine di successione, con il quale appaiono le scissure cerebrali," *Processo Verbale della Soc. Toscana di Sci. Nat.*, 1882.

[3] "Ueber die Entwicklung der Furchen und Windungen des Menschlichen Gehirns," *Untersuchungen zur Naturlehre des Menschen und der Thiere*, herausgegeben von Jac. Moleschott, xiii. Band, 6 Heft.

[4] *British Medical Journal*, June 6, 1874.

Richter I have also found useful, although those which we commonly see in our text-books, and which have been taken from Ecker and Mihalkovics, cannot be regarded as giving a proper idea of the transitory furrows as they exist during the period of their maximum development.

Duration of the Transitory Fissures.—The mesial wall of the hemisphere is considerably thinner than the outer wall, and it is partly in consequence of this that the transitory fissural infoldings first make their appearance upon it. But we have the most conflicting statements regarding the actual period at which they first begin to be formed, and also regarding the time at which they vanish. These views will best be understood if I place them in tabular form :—

Duration of Transitory Furrows.

Authority.	Period of Appearance.	Period of Obliteration.
Meckel.	8th to the 9th week.	......
Schmidt.	Middle of the 3rd month.	End of the 4th month.
Ecker.	3rd to the 4th month.	Commencement of the 5th month.
v. Kölliker.[1]	3d month.	5th month.
Mihalkovics.	Middle of the 3rd month.	Commencement of the 4th month.
Romiti.	10th week.	End of the 4th month.

We may remark here that the description given by Schmidt hardly agrees with his figures, because the transitory fissures are indicated by him on the mesial surface of a cerebrum taken from an embryo at the eighth week, which bears out the original observation of Meckel.

The difference of opinion which is shown in the above table results no doubt very largely from variations in the duration of these fissures, but it is likely that it is also in a great measure due to the almost insuperable difficulty of giving to an embryo its proper age. As I have stated, the embryos which I have specially studied with the view of obtaining a knowledge of the transitory fissures ranged from about the third month to about the end of the fourth month. In all of these the transitory fissures were visible. Clearly Mihalkovics is wrong in limiting the time of their existence to one fortnight. It appears equally

[1] *Entwicklungsgeschichte des Menschen und der höheren Thiere.*, 1879.

certain that they may begin on the mesial face of the hemisphere as early as the eighth week. Meckel has told us so, and Schmidt has figured them at this stage; but they do not attain, even on this aspect of the hemisphere, a high degree of development until the ninth or tenth week.

On the outer surface of the hemisphere their formation is delayed. It is doubtful if they ever show on this aspect before the tenth week. In most cases they attain their maximum degree of development between the third and fourth months, and this holds good for both surfaces of the hemisphere.

A certain amount of latitude must also be allowed in reckoning their time of disappearance; but as a rule it will be found that they become obliterated between the periods at which the fornix and corpus callosum become developed; in other words somewhere towards the end of the fourth month. From this general statement, however, we must make an exception in favour of two fissures which appear on the outer aspect of the occipital lobe, and whose history I purpose discussing at some length further on.

Transitory Fissures on Medial Wall of Hemisphere.—As a general rule, the transitory fissures on the mesial wall of the hemisphere are very definite in their relations, although they vary greatly in number. They consist of a series of furrows which radiate in a stellate manner from the fissura arcuata

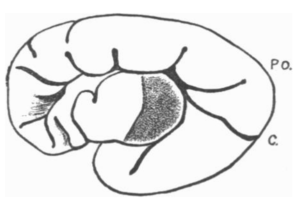

FIG 1.—Mesial surface of the right hemisphere of a fœtus about the twelfth week, or a little later. P.O, the precursor of the parieto-occipital fissure; C, the precursor of the calcarine fissure.

(*Bogenfurche*) towards the free border of the hemisphere. At first they appear as a number of notches or indentations in the upper boundary of the fissura arcuata. These are shallow and broad at the base, and they give to the medial cerebral wall a wrinkled or crumpled appearance. At this stage they might very readily be mistaken for depressions brought about by the shrinkage caused by a hardening reagent. After a while they deepen and lengthen out, and they may extend as a continuous series all the way round from the frontal pole in front to the extremity of the temporo-sphenoidal lobe below (fig. 1). The majority of the transitory fissures on the medial face of the hemisphere do not reach so far as the border of the hemisphere, but two at the occipital or postero-superior pole, very constant in position and longer than the others, almost invariably do so; and, occasionally, in the frontal region and at the end of the temporal lobe one or more may also show a similar extension.

As we have stated the number of radiating temporary fissures on the medial aspect of the hemisphere varies very greatly. In one cerebral hemisphere Richter counted nine, and in another only five. The number is usually the same, or approximately so, on the two hemispheres of the same brain, and the usual number seems to be eight. Eight hemispheres, all between the third and fourth months, yielded the following results in this respect:—

In *four* the number was, ...	8
„ *two* „ „	6
„ *one* „ „	9
„ *one* „ „	5

No doubt the difference in the number of fissures on the medial surface is partly due to the different periods of development at which the brains were examined, but I do not believe that this is the only factor present in determining the variations. The influence at work in calling the infoldings of the cerebral wall into existence appears to be a purely mechanical one, viz., a restraint placed upon the longitudinal growth of the hemisphere, and this being the case it is easy to understand how the number and depth of the fissures will vary with the degree and kind of restraint which is applied.

Primitive Cuneate Subdivisions of the Medial Hemisphere Wall.—By the presence of the stellate fissures, when they are developed in a marked form, the medial surface of the hemisphere outside the fissura arcuata is subdivided into a number of wedge-shaped or cuneate portions. That portion which intervenes between the two long fissures, which we have mentioned as being always present on the occipital part of the hemisphere, is retained as the cuneus of the adult brain. The other portions in front of this region, and also those below it, again run into each other when their bounding fissures are obliterated, and they then form the smooth tracts out of which the gryus fornicatus, calloso-marginal convolution, precuneus, and the convolutions on the under surface of the occipital and temporal lobes are ultimately formed. The primitive fissures which bound the cuneus proper are the precursors of the calcarine and parieto-occipital fissures.

Obliteration of the Transitory Fissures.—To study in all its details the manner in which these transitory fissures disappear and vanish from the mesial surface of the hemisphere, so as not to leave a single trace of their former existence, either on the outside or inside of the cerebral wall, would require a greater number of specimens, and these more varied as to the term of

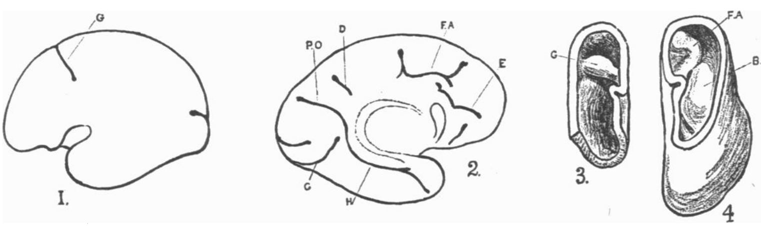

FIG. 2.—A series of views of the cerebrum of a fœtus about the end of the fourth month, or a little later. No. 1, outer surface of the left hemisphere. No. 2, mesial surface of the left hemisphere; E. and D, detached radial fissures; F.A, anterior detached part of the fissura arcuata; H, hippocampal fissure; C, precursor of the calcarine fissure; P.O, parieto-occipital fissure. No. 3, the roof of the right hemisphere removed and turned so as to expose its ventricular aspect; G, the infolding corresponding to the fissure marked by the same letter in No. 1. No. 4, the left hemisphere with the roof removed; F.A, the infolding corresponding to the anterior detached part of the fissura arcuata.

their development than those which I possess. Still in the material at my disposal a number of interesting points may be determined. As the wall of the cerebral vesicle thickens and the hemisphere elongates one or more become detached from the fissura arcuata (fig. 2, No. 2, D.). They then appear as isolated short fissures. These continue to decrease in length until they appear as little more than a point, corresponding with which a small rounded elevation is seen on the inner aspect of the wall of the ventricular cavity. Finally, this disappears also, and both aspects of the wall become smooth. Although I have observed the detachment of the fissures from the fissura arcuata on the medial aspect of the hemisphere, I have not been able to follow the subsequent stages of obliteration. On the outer wall of the hemisphere, however, these stages can be easily traced, and in fig. 12 (No. 3, E.C., p. 337) the rounded ventricular elevation, the remains of an inward fold, may be seen.

But, as we have previously mentioned, the fissura arcuata itself may break up (fig. 2, No. 2). In all cases the posterior hippocampal portion (H) is preserved *in situ*, and, in connec-

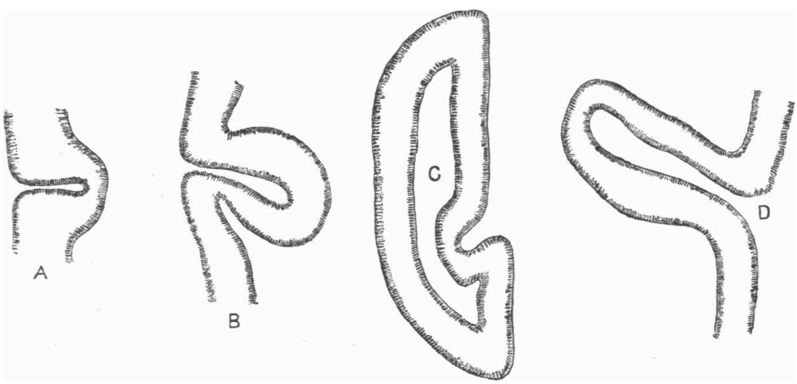

FIG. 3.—Microscopical sections through certain of the infoldings of the right hemisphere, which is depicted in fig. 2, viz., Nos. 2 and 3. A, section through the upper part of the infolding marked G in fig. 2; B, section through the middle of the same infolding; C, section through the anterior part of the same cerebral hemisphere, showing the anterior detached radial infolding which is marked E in fig. 2; D, section through detached anterior part of the fissura arcuata.

tion with this, the precursors of the calcarine and parieto-occipital fissures may remain attached. The anterior part (F.A.), with whatever radial fissures still adhere to it, assumes a more elevated position on the mesial wall of the hemisphere; and I have already given expression to the view that it also may become obliterated. Whether this is the usual course of development or not I cannot say, as I only possess one brain in which the process is seen. The left hemisphere of this specimen is represented in fig. 2. Two isolated radial fissures are seen in course of obliteration—one on the inner face of the frontal lobe (E.), and the other (D.) a short distance in front of the precursor of the parieto-occipital fissure. The hippocampal fissure, with the precursory calcarine and parieto-occipital furrows are very evident (H.; C.; and P.O.). The anterior part of the fissura arcuata is greatly shortened; it has two radial furrows in connection with it, and it has broken away completely from the hippocampal fissure, and presents all the appearances of being in process of obliteration. The right hemisphere of the same brain showed a condition almost identical with that of the left side. Fig. 2, Nos. 3 and 4, gives a view of this hemisphere with the roof removed. The deep infolding caused by the anterior part of the fissura arcuata is seen stretching outwards upon the floor of the ventricle. In figure 3 (C) a transverse microscopical section through the fore part of the hemisphere is exhibited, as seen under a low magnifying power. The infolding corresponding to the anterior detached radial fissure (fig. 2, No. 2, E.) is seen. In the same figure (D.) a similar transverse section through the front detached part of the fissura arcuata is depicted. The depth of this infolding is very remarkable.

Transitory Fissures on the Outer Surface of the Hemisphere.—The transitory fissures are not, as a rule, disposed so

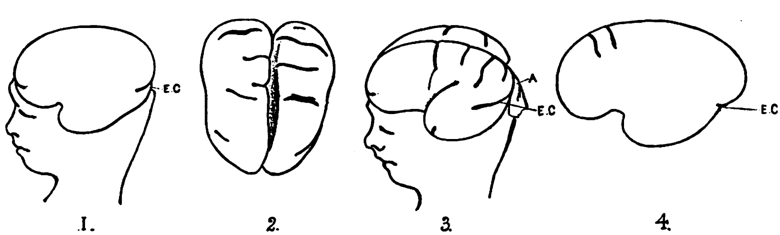

FIG. 4.—No 1, right hemisphere of a fœtus about the eleventh week. Nos. 2 and 3, different views of a fœtal brain between the thirteenth and fourteenth week. No. 4, left hemisphere of a fœtus about the end of the twelfth week, or a little later ; E.C., precursor of the external calcarine.

uniformly on the outer face of the hemisphere as they are upon the medial face. They show a tendency, however, to assume a similar arrangement. Starting from the free border of the hemisphere, they run in a convergent manner towards the

Sylvian region, or, in other words, towards the hilum of the bean-shaped cerebrum; but in all cases they fall short of this. In well-marked cases they are present all the way round the mantle border from the frontal pole in front to the temporo-sphenoidal pole below. At some particular part of the circumference it is usual to see them more concentrated or more closely placed and more numerous than elsewhere. In certain cases this may occur in the frontal region (fig. 4, No. 4, and fig. 5, Nos. 2 and 4); in other instances it is in the parietal region that the crowding together takes place (fig. 4, Nos. 2 and 3).

But the fissures have not always the simple and uniform arrangement described above. With these, others are usually associated. Thus, it is by no means uncommon to see a fissure occupying a position and possessing a direction similar to that of the adult Sylvian fissure (fig. 5, Nos. 1, 2, 3, and 4; also fig. 4, No. 3, &c.). In eight hemispheres examined this was present in five instances, and it was no mere superficial furrow, but a deep cleft, which separated the upper and front part of the cerebrum from the lower and back portion almost as effectually as the clefts of the lung separate its various lobes. Altogether this is a most striking infolding. It is seen in great perfection in one of the specimens displayed in the museum of the University College, London (fig. 5, Nos. 1, 2, 3). All the brains in which it occurred I reckoned to be about the same period of development, viz., from the thirteenth to the fourteenth week. In brains younger than this (fig. 4, No. 1), or older (fig. 4, No. 4, and fig. 2, No. 1), there is not a trace of it. At the same time, I am not prepared to say that this remarkable fissure is always present. It is clear, however, that there is a marked tendency towards the formation of such a fissure under certain conditions of growth-restraint, and that these conditions appear to be usually present. It is further apparent that the presence of such an infolding in this locality must influence the development of the fossa Sylvii. This aspect of the question I purpose postponing for future consideration, seeing that at present we are merely engaged with the study of the complete fissures, and the Sylvian fossa does not fall within this group.

In one hemisphere a second deep cleft was present, below and parallel to that just described. It therefore occupied the ground of the future parallel sulcus of the more fully-developed brain (fig. 5, No. 3, B.); but, whilst this is the case, I would not for a moment hint that it has anything to do with the development of the adult sulcus of that name.

Again, it is by no means unusual to observe short isolated fissures removed a short distance from the free border of the hemisphere. They are, doubtless, fissures in process of obliteration. They are chiefly to be noticed in specimens between the third and the fourth month (fig. 4, No. 2, and fig. 5, Nos. 3 and 4).

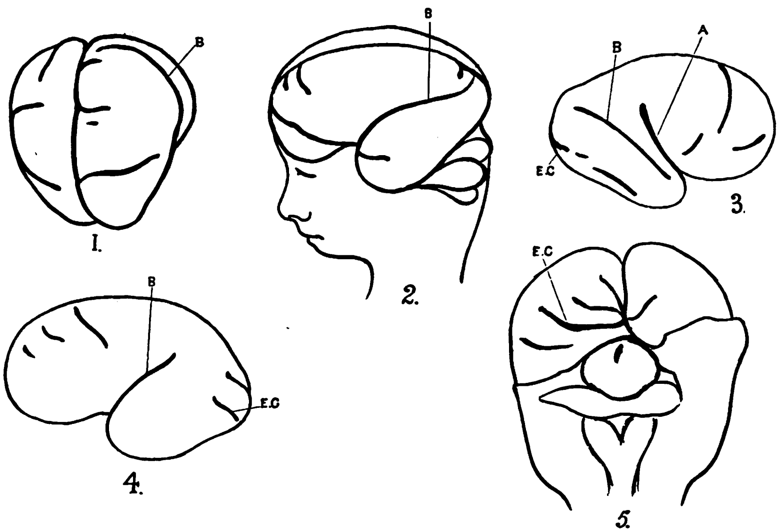

FIG 5.—Series of cerebral hemispheres between the thirteenth or fourteenth week of development; E.C, external calcarine; A, deep infolding in position of Sylvian fissure; B, another in position of the future parallel fissure.

In certain hemispheres the fissure on the mesial face, which we have named, provisionally, the precursor of the calcarine fissure, is carried horizontally round the occipital pole, cutting it deeply, and appearing on the outer surface in the form of a fissure, which we may term the *external calcarine* (fig. 5, No. 5, E.C.). This fissure has a most interesting history, which I purpose tracing at a later stage of this paper. In the meantime, I may merely call attention to the fact that this external calcarine fissure was present in the great majority of the hemispheres examined, although it was not, in every case, continued round the occipital pole into the precursor of the calcarine fissure on the medial face of the cerebrum (figs. 2, 4, and 5, E.C.).

In figure 4 (No. 1) the left hemisphere of an embryo at about the eleventh week is represented. Two short fissures—one in front and the other behind—are alone present on the outer surface of the cerebrum. Between these, however, the cerebral mantle is faintly streaked by a series of faint grooves, which present very much the direction of the transitory fissures when fully developed. Most likely these markings indicate the initial stages in the formation of the fissures. When fully formed, a deep infolding is the result. Figure 3 (B.) shows a transverse microscopical section through the middle of the fissure indicated in the frontal region of the brain depicted in figure 2, No. 3, G. The lips of the furrow are closely applied to each other at the surface, and it is this that gives to such fissures their sharply-cut linear appearance; but, towards the bottom of the sulcus, the walls of the fold are separated to a small extent, and a slight recess is formed between them. Schmidt has stated that, at the places where the bending-in of the cerebral wall takes place, the wall of the hemisphere is thinner than elsewhere. This is well seen in figure 3 (B.), although on the one side of the fissure it is better marked than on the other. At the same time it must be noted that this condition is not universally present. In the shallow parts of a fissure, or where a fissure is shallow throughout, it is the bottom of the fold that becomes thinned (fig. 3, A. and C.). When a continuous series of sections is made through the entire length of one of the transitory fissures the central part is seen to be very deep (fig. 3, B.), while at its two extremities it is shallow, and the bottom gradually rises to the surface (fig. 3, A.). The folds, therefore, as seen from the ventricular aspect, present a semilunar form (fig. 2, No. 3, G.).

A study of the various specimens would seem to indicate that the process of obliteration consists in a shortening of the fissure from both extremities towards the centre. More and more of the bottom of the furrow rises to the surface, until at last the deep central part alone remains in the form of a round knob-like elevation on the ventricular aspect of the wall (fig. 10, Nos. 3 and

4, E.C.). Ultimately this disappears also. During this process the fissures retreat from the hemisphere margin, and in several of the figures which are given (fig. 4, No. 2, and fig. 5, Nos. 3 and 4), one or more of these may be observed. But it is necessary to mention here what we shall have to insist upon more fully hereafter, viz., that this obliteration does not appear to depend solely upon a process of unfolding, but that a certain amount of absorption of the fold appears also to take place.

On the outer surface of the hemisphere, just as on the mesial surface, the number of transitory fissures present varies very considerably. Ten hemispheres of embryos, ranging from the tenth week or so up to the end of the fourth month, gave the following results:—

In *none* was the outer surface smooth.
„ 4 there were 8 fissures.
„ 1 „ „ 7 „
„ 1 „ „ 5 „
„ 1 „ „ 4 „
„ 2 „ „ 3 „
„ 1 „ „ 2 „

It is interesting to note that the number most commonly present was eight, just as in the case of the mesial surface.

In only one brain were the fissures arranged absolutely symmetrically on the two hemispheres. This was, perhaps, the most instructive specimen of the series, and several views of it are given in fig. 2, p. 318. Although not disposed in the other brains in exactly the same way on the two sides, there was always noticed a general correspondence between the two hemispheres in the number and character of the fissures. Thus, two of the hemispheres in which eight fissures occurred belonged to the same embryo, whilst in another case there were eight on the one side and seven on the other.

A very interesting question arises at this point—Do circumstances ever arise under which these transitory fissures of the early cerebrum are retained permanently? There is good reason to believe that in many cases those we have named the precursors of the parieto-occipital and calcarine show an unbroken continuity of existence with the fissures which bear the same name in the fully-developed brain. Further, the corresponding fissures on the outer face of the occipital lobe (external perpendicular of Bischoff and external calcarine), in rare instances, may also be preserved. Certainly they always enjoy a much more prolonged existence than the other transitory fissures. Lastly, there cannot be a doubt that in certain malformations of the brain, as, for example, absence or defective formation of the corpus callosum, this primitive and, under normal circumstances, transitory fissural system is in a measure preserved. Anton [1] is of opinion that the disappearance of the transitory furrows is largely due to the development of the corpus callosum. It is no doubt true that the obliteration is very nearly synchronous with this, but whether it is caused by it is altogether another matter.

Recently Dr Alexander Bruce has published in the *Proceedings of the Royal Society of Edinburgh* (vol. xv.) a very able paper upon a case of congenital absence of the corpus callosum. The admirable drawing which he gives of the inner face of the cerebrum is most suggestive. There is not a trace of the calloso-marginal fissure, but, radiating from the fissura arcuata towards the free border of the hemisphere, there are a number of diverging sulci. These are undoubtedly to be regarded as the primitive and usually transitory fissures which are always present on the mesial face of the hemisphere during its early stages of development, and which in this case have been preserved. Equally instructive are the figures given by other authors of this face of the cerebral hemisphere in brains with no corpus callosum. Those of Eichler,[2] Knox,[3] and more especially of Onufrowicz,[4] show the retention of the transitory fissural arrangement in the most marked manner.

But it is not on the inner surface alone that the transitory fissures may be retained. Hans Virchow [5] has described and figured a very extraordinary brain, in which the corpus callosum was absent in connection with hydrocephalus internus. The fissural type (fig. 6) on both aspects of the cerebral hemisphere is that of the period of the transitory fissures, With reference to those on the outer surface, he remarks :—" Ebenso auffallend ist die Abweichung vom Typus bei den Furchen. Es ist gewissermassen der normale Typus gänzlich aufgehoben und durch einen neuen Typus ersetz, welcher an die

[1] *Zeits. für Heilkunde*, Band vii., 1886.
[2] *Archiv f. Psychiatrie*, vol. viii. pt. 2, 1878.
[3] *Glasgow Medical Journal*, 1885.
[4] *Archiv f. Psychiatrie*, vol. xviii., 1887.
[5] " Ein Fall von angeborenem Hydrocephalus internus, zugleich ein Beiträg zur Mikrocephalen Frage," v. Kölliker's *Festschrift*, 1887, Leipzig, p. 305.

Zustände beim ersten Auftreten der Furchen dadurch erinnert, dass eine Tendenz zu radiären Anordnung die Furchen beherrscht." But it is not a persistence of the "radiären Primärfurchen" of Reichert,[1] Bischoff,[2] and Pansch[3] that this brain shows, but the retention of the much earlier transitory fissures.

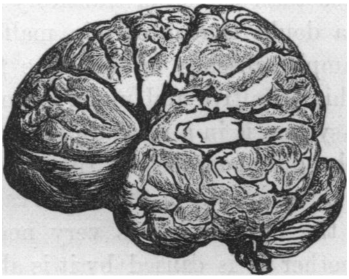

FIG. 6.

In Dr Bruce's case of absent corpus callosum, the fissure of Rolando was situated very far forward, and was continued over the upper border of the cerebrum on to the mesial face of the hemisphere. We might naturally question, therefore, whether or not it was the true fissure of Rolando or merely a furrow produced by the retention of one of the primitive transitory fissures. Such a fissure as is represented in figure 2 (No. 1, G.) would stand for it. The direction of the Rolandic fissure in Dr Bruce's case—viz., from above downwards and backwards—would lend some support to this view.

In speaking of the disposition of the fissures on the mesial face of the cerebrum in his specimen of absent corpus callosum, Dr Bruce remarks:—

"The radiated convolutionary arrangement is very difficult to explain. It may be due to the mechanical resistance offered by the ring-like marginal arch to the growth of the grey matter of the gyri. This will thus become furrowed, much as a bag made of cloth when a string is tied tightly round its neck. In this case, too, the furrows radiate outwards from the string. The abnormal mesial fissure of Rolando is not found in other cases. I am at a loss to account for it, except on the view that the forward growth of the brain has surpassed that of the cranium, and that a duplicature of the inner surface was thus produced." This is a most ingenious explanation, and may in part be applied to the production of the primitive furrows on the inner aspect of the hemisphere in the early stages of normal brain-growth.

[1] *Der Bau des Menschlichen Gehirns*, Leipzig, 1861.

[2] "Die Grosshirnwindungen des Menschen," *Abhandl. der k. bayer Akad. der Wiss.*, 11 Cl. x Bd. 11 Abth.

[3] "Ueber die typische Anordnung der Furchen und Windungen auf den Grosshirnhemisphären des Menschen und der Affen," *Archiv f. Anthrop.*, Dritte Band, Drittes und Viertes Heft, 1869.

Parieto-occipital and Calcarine Fissures.—The views which have been advanced by different authors regarding the origin of the parieto-occipital and calcarine fissures are very conflicting, and no doubt there are many points in connection with their first appearance and history which are extremely puzzling.

v. Kölliker[1] maintains that they appear synchronous with the temporary fissures on the mesial aspect of the hemisphere, and constitute members of the same series—differing from them only in so far that they are permanent and not evanescent. He says:—"As early as the separation of the frontal lobe from the temporal lobe by the Sylvian fossa there arises a boundary for the occipital lobe by the appearance of the parieto-occipital fissure. This is distinct in the third month. Schmidt even figures it in the eighth week." Richter,[2] who gives a good account of the transitory furrows in a series of early embryos, appears to entertain the same view. Referring to a brain with hemispheres 3·3 c.m. long, he remarks:—"An der medialen Seite der Hemisphären gingen einige radiäre Falten mehr von der Bogenfurche aus als bei Fötus 3. Bei letzerem zählte man im Verlauf der ganzen Bogenfurche fünf, bei Fötus 4 neun. Die Fiss. parieto-occ. und calc. standen bei Fötus 4 zur Bogenfurche ungefähr noch in demselben Verhältniss wie bei Fötus 3. Ausser der Parieto-occ. und calc. verschwinden übrigen diese radiären Furchen der medialen Hemisphärenwände dieser Entwicklungsepoche sammt und sonders wieder und theilen so das Geschick der schon früher erwähnten occipitalen Falten früherer stadien, obschon sie wie diese Totalfalten im His'schen sinne sind."

Ecker[3] expresses himself on this question with considerable doubt and caution. "Moreover," he remarks, "it appears to me that one of the latter, viz., the fissura parieto-occipitalis is formed out of one of the temporary furrows, although I do not venture to assert this." This statement is rendered all the more ambiguous by the fact that in his description of the brain of a third-month fœtus he asserts that the occipital lobe does not exist. Undoubtedly the fissure in dispute (the precursor of the parieto-occipital) is present at this stage. Further, he figures the parieto-occipital and the calcarine fissures in a brain at the fourth month, although he appears to infer that they arise more frequently in the course of the fifth month.

According to Mihalkovics,[4] the calcarine fissure is the first to appear. It is formed at the end of the third month, and arises with the outgrowth of the occipital lobe almost simultaneously with the transitory furrows. The parieto-occipital sulcus is formed shortly after it at the commencement of the fourth month.

1 *Entwicklungsgeschichte des Menschen und der höheren Thiere*, 1879.

2 "Ueber die Entstehung der Grosshirnwindungen," *Virchow's Archiv*, 1887, p. 398.

3 "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirnhemisphären im Fœtus des Menschen," *Archiv für Anthrop.*, 1869.

4 *Entwicklungsgeschichte des Gehirns*, Leipzig, 1877.

Having now stated the views of those authors who have dealt with this question, I shall proceed to state the conclusions at which I have arrived regarding the parieto-occipital and calcarine fissures in the course of my study of the complete fissures.

At the same time, that the transitory fissures appear on the medial face of the hemisphere (towards the end of the second month, or it may be towards the beginning of the third month) two fissures which have a synchronous origin, and lie in series with these, occupy positions which give them a close resemblance to the parieto-occipital and calcarine fissures of the fully-developed brain. Between them is placed the cuneus. I have never seen these fissures absent, and in all good illustrations of the medial face of the hemisphere (v. Kölliker, Richter, &c.) they are represented. We have already referred to these infoldings as the precursors of the parieto-occipital and calcarine fissures.

One or other, or perhaps in some cases both, of these precursors may be retained and ultimately form the respective adult fissure or fissures. Most frequently, however, one disappears whilst the other is preserved. That which is obliterated is replaced later on (in the fifth month, or towards the beginning of the sixth month) by the permanent furrow, and this takes up the same ground as its precursor, although it does not show an unbroken continuity of existence with it. It is questionable if both precursors ever disappear again to be replaced by secondary successors.

It is difficult to say which of the precursory infoldings most frequently disappears. I am of opinion, however, that it is the parieto-occipital, and this view is quite in keeping with the phylogenetic evidence which we have on the question. In the Apes there cannot be a doubt but that the calcarine fissure is the most stable of the two. About the fifth month of intra-uterine life it is not uncommon to find hemispheres in which the parieto-occipital is totally absent, although the calcarine is present (fig. 7, B. and C.). Sometimes, however, at this stage, in addition to a well-marked calcarine fissure, a faint trace of the parieto-occipital may be visible. In two hemispheres from the same fœtus, in my possession, the calcarine alone is present on the left side, whilst on the right side there is also a weak indication of the parieto-occipital (fig. 9, A. and B.). It is hard to determine in this case whether the faintly-marked parieto-occipital is in process of obliteration, or in process of formation. On the ventricular face of the hemisphere wall a prominence corresponded with the weakly-marked parieto-occipital fissure, and this taken in conjunction with the fact that in the initial stages of the reappearance of the calcarine fissure, in cases where its precursor has been obliterated, I have failed to detect such a projection, makes me incline to the view that the parieto-occipital in this instance is really in process of obliteration.

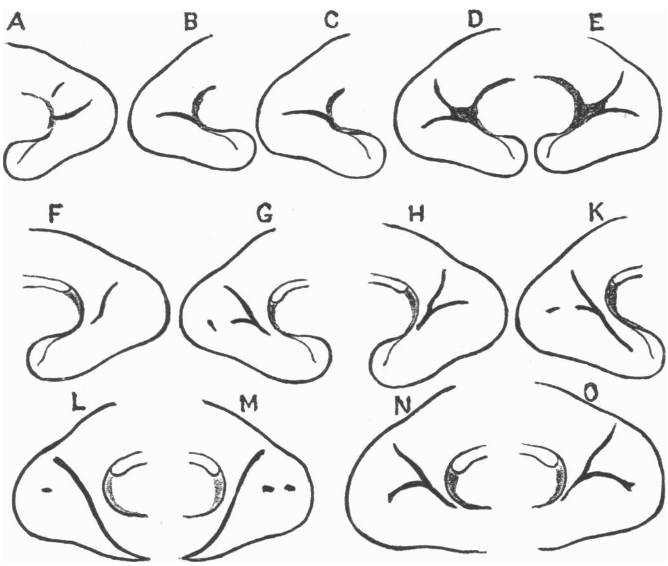

FIG. 7.—Different forms assumed by the parieto-occipital and calcarine fissures at different stages of their development.

His[1] has called attention to the fact that in certain fœtal brains of the fifth month the calcarine fissure may exist alone on the one hemisphere, whilst on the other the parieto-occipital only is developed.

But from the beginning of the fifth month, and onwards, another condition is frequently met with. In this both fissures

[1] *Unsere Körperform*, Neunter Brief, p. 114.

are present (fig. 7, D. and E.). They converge towards a broad shallow gutter or furrow, by which they are led forward into the hippocampal fissure. The typical ≺-shaped condition is thus assumed, and this persists throughout the further development of the brain. In such a case it is probable that we have a retention of both precursory fissures. His figures a hemisphere which shows this disposition of the fissures, and he considers that the brain from which the drawing is taken had reached a stage of development corresponding to four and a half months. From the fact, however, that the corpus callosum is represented in the fully-developed condition, and that traces of the calloso-marginal sulcus are indicated, it is likely that the fœtus from which the brain was taken was somewhat more advanced.

I have only seen one hemisphere in which the parieto-occipital fissure was present alone, without a trace of the calcarine [1] (fig. 7, F.). This belonged to a fœtus which had reached a stage of development corresponding to the end of the fifth month. On the other hand, I have observed several in which the parieto-occipital was the predominant fissure, and in which the calcarine was so poorly developed that we could only conclude that it was in its initial stages of reappearance. It is somewhat curious that the hemispheres in which this condition was present were all at a somewhat advanced stage of development, viz., at the sixth month, or at least close upon it. In these cases the reappearing calcarine may assume several forms:—(1) It may appear as a short, weak branch, stretching backwards for a short distance from the lower part of the parieto-occipital (fig. 7, H.); (2) as a short branch in connection with the parieto-occipital, but also with an additional small detached piece lying nearer the occipital pole, and in the line of the future fissure (fig. 7, G. and K.); (3) as one or two detached and isolated pieces which lie in the line of the future fissure, and which are in no way connected with each other or the parieto-occipital fissure (L. and M.).

This last mode of development, viz., by isolated portions which ultimately run into each other, is frequently observed in con-

[1] Since writing the above two additional hemispheres of this kind have come into my possession.

nection with the cortical and permanent sulci. Thus the intraparietal, the calloso-marginal, and the supero-frontal sulci frequently afford examples of this; and it is even not uncommon to see the same mode of development in the case of the fissure of Rolando.[1] When a section is made through the occipital lobe, in cases where the calcarine fissure is merely represented by these slight depressions, it is seen that they produce no corresponding elevation on the ventricular aspect of the hemisphere wall.

In both hemispheres of a fœtus which had arrived at the end of the fifth month, or the beginning of the sixth month, the parieto-occipital fissure presented a very remarkable development. Instead of ending a short distance below the hinder end of the corpus callosum, it was prolonged downwards and forwards as a deep fissure, which reached the lower border of the temporo-sphenoidal lobe (fig. 7, L. and M.). The calcarine fissure was present as two short isolated portions or depressions, and the part of the parieto-occipital fissure below the line of these was at least three times as long as the part above. The long lower part must be regarded as transitory. In the further development of the brain it would in all probability have become obliterated. In this case the appearance presented by each hemisphere suggested as the cause of this long fissure the bending, in an inward direction, of the entire hinder part. The fissure formed the angle of bending.

The typical <-shaped condition of the combined parieto-occipital and calcarine fissures appears to be invariably assumed between the sixth and seventh months of fœtal life (fig. 7, N. and O.), although, as we have seen, it is frequently assumed at the fifth month. Even at the seventh month, however, it is not at all uncommon to find a marked difference in the degree of development of the two fissures, and in the manner in which they influence the ventricular aspect of the cerebral wall in different brains. In some cases it is the calcarine which is deepest and continuous with the stem of the <. A distinct hippocampal elevation on

[1] The fact that the fissure of Rolando may first appear in two pieces—one near the free border and the other near the Sylvian fossa,—which ultimately run into each other, shows at once how erroneous the view advanced by Krause as to its origin is. To this we shall refer in a subsequent chapter of this memoir.

the ventricular aspect of the hemisphere wall marks its course. The parieto-occipital fissure in such cases is a shallow furrow, and produces no ventricular eminence. In other instances exactly the reverse condition may be noticed. The parieto-occipital fissure is present as a deep infolding, continuous with the stem of the <, whilst the calcarine fissure is shallow. Consequently, on opening the posterior horn of the ventricular cavity by the removal of the outer wall, very different appearances may be seen in different brains:—(1) Two elevations, corresponding to the two fissures, may be seen on the ventricular aspect of the inner wall. I do not possess a specimen which shows this condition, but, where both fissures persist from the precursory stage, it is reasonable to assume that the corresponding ventricular elevations will persist also. (2) In other instances, one ventricular elevation alone is present. This may correspond with the calcarine, in which case it proceeds in a more or less horizontal direction from behind forwards, or it may correspond with the parieto-occipital, in which case it descends from above, and takes a curved direction from above downwards and forwards. The deep fissure with the infolding on the ventricular aspect of the hemisphere wall may be regarded as the one which has persisted from the precursory stage. The other is secondary, having been, in the first instance wiped out prior to its permanent reappearance.

Greatest Depth in Millimetres of the Parieto-occipital and Calcarine Fissures.

No. of Observation.	Age of Fœtus.	Parieto-occipital.		Hinder part of Calcarine.	
		Right Hemisphere.	Left Hemisphere.	Right Hemisphere.	Left Hemisphere.
1	Commencement of 7th month	2	4	3	1
26	28 weeks	2	1	2	—
11	7th month	4	4	2	2
38	29 weeks	3	3	5	4
25	29 weeks	5	4	5	5
15	30 weeks	6	7	3	2

N.B.—Large figures are used where there is a striking difference in the depth of the calcarine and parieto-occipital fissures on the same hemisphere.

A study of an excellent paper, which has recently been published by Dr J. Mingazzini[1] of Rome, makes it very evident that about the beginning of the seventh month it is extremely common to find one fissure deep and the other shallow. I may be allowed to extract from the useful tables which this author gives the items contained in the Table on preceding page:—

Pansch[2] raises a question as to the position which the stem of the ≺ occupies with reference to the two fissures. He says:—

> "Zu welchen dieser beiden der Stamm des Y gehört, oder ob dieser wechselt, oder ob er weilleicht zuweilen isolirt ensteht, wage ich noch nicht endgültig zu entschieden."

This is an important question, because in the adult human brain it is the back part of the stem which is chiefly related to the calcar avis. The parieto-occipital fissure above the stem has no relation whatever to the ventricular cavity, because above the level of its junction with the calcarine fissure the cerebral hemisphere has become solid through the increase of the white substance. If the stem, therefore, does not belong to the parieto-occipital, this fissure forms no permanent bulging into the ventricular cavity.

Upon phylogenetic grounds, we might infer that the stem belongs solely to the calcarine fissure. In the Chimpanzee the parieto-occipital does not run into it, but is separated from it by a thick superficial convolution. In many human brains this convolution is represented by a deep bridging gyrus, which acts as a feeble barrier to the free communication between the two fissures. In the Orang the condition may be exactly the same as in the Chimpanzee, or resemble that present in Man. In an Orang's brain in my possession the right hemisphere shows a free communication between the parieto-occipital and calcarine fissures, whilst on the opposite side the two fissures are completely separated by a superficial convolution.

But on studying the ontogenetic evolution of the two fissures, it becomes apparent that in the human brain the stem of the

[1] "Ueber die Entwicklung der Furchen und Windungen des Menschlichen Gehirns," aus *Untersuchungen zur Naturlehre des Menschen und der Thiere*, herausgegeben von Jac. Moleschott, xiii. Band, 6 Heft.

[2] "Ueber die typische anordnung der Furchen und Windungen," &c., *Archiv für Anthrop.*, 1869, p. 232.

>- may have a different connection in different specimens. In cases where both fissures persist from the precursory stage the stem is common to both. It is the lineal descendant of the broad shallow gutter, which we have noticed in some brains at the fifth month, leading forwards to the hippocampal fissure. It is formed by a depression of that portion of the primitive gyrus fornicatus, which lies between the two anterior extremities of the precursory fissures. In other cases, it is formed by that fissure, which persists after the obliteration of its fellow. Sometimes, therefore, the stem belongs to the parieto-occipital, sometimes to the calcarine, whilst there are still other instances in which it is common to both.

This affords an explanation as to the very different degrees of development we continually observe in the calcar avis in the adult human brain. When the calcar avis is small and feebly marked, it corresponds only with the back part of the stem of the -<, and in this case it is probable that the parieto-occipital fissure is solely responsible for its production. When, on the other hand, it is a strongly marked prominence it will be seen that it is related not only to the stem of the -<, but also to a portion of its calcarine branch.

In the Chimpanzee the calcar avis is very strongly marked, and produced from end to end by the calcarine fissure. Close to the place where the posterior horn joins the body of the ventricle another elevation, placed above the calcar avis, is sometimes to be remarked, and this seems to correspond with the lower end of the parieto-occipital fissure. It is right to add, however, that although I have made sections of two hemispheres from different brains, with the view of clearing up this latter point, I cannot say that I am absolutely satisfied upon it.

External Calcarine and External Perpendicular Fissures. —In his elaborate memoir upon the convolutions of the human brain and their development in the fœtus, Bischoff[1] describes and figures a transitory fissure on the outer surface of the cerebral hemisphere under the name of "fissura perpendicularis externa." He states that it appears in the seventh month in the form of a furrow, which runs downwards in a

[1] *Abhandl. der k. bayer Akad. der Wiss.*, 11 Cl. x. Bd. 11 Abth.

vertical direction over the hinder end of the hemisphere, and that it is obliterated in the eighth month. It belongs to that class of formations, therefore, he remarks, which only in certain forms attain their complete development, whilst in others they are arrested or completely disappear.

That such a fissure occasionally exists there cannot be a doubt. Further, it is a complete fissure, and produced by a distinct infolding of the hemisphere wall. But Ecker has very rightly pointed that it is not between the seventh and eighth months of fœtal life that it is to be seen, but much earlier. It appears, according to Ecker, in the fifth month, but disappears before the sixth month is reached.

On very few occasions have I ever seen the fissura perpendicularis externa as it is figured by Bischoff. The best example which has come under my notice is in a brain apparently a little over the fifth month, which is preserved in the museum of the Oxford University, and of which Professor Horsley has very kindly given me a photograph. A tracing from this is repro-

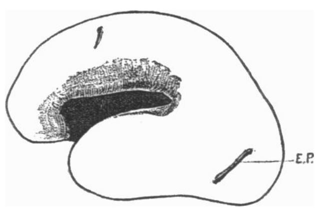

FIG. 8.

duced in the text (fig. 8, E.P.). The fissure in question is situated on the outer surface of the occipital lobe very much on a line with the parieto-occipital fissure on the medial face of the hemisphere, but it is placed a little further back. It therefore occupies the position of the "Affenspalte" in the Ape's brain, and I have little doubt that Bischoff is right in supposing it to be the representative of the latter.[1] In the January number of this *Journal* I have endeavoured to show that the sulcus transversus of Ecker cannot (in its entirety at least) be regarded as equivalent to the "Affenspalte," and this being

[1] In a former paper upon the "Intraparietal Sulcus" (*Journ. Anat. and Phys.*, Jan. 1890), I expressed a different opinion, but I am now satisfied that in this I was wrong.

assumed, the fact of the early disappearance of Bischoff's fissura perpendicularis externa cannot be quoted as evidence against its being the transitory representative in the human fœtus of the "Affenspalte." Lately I have obtained the brain of a newly-born male child (fig. 9), which shows a condition bearing very closely upon this question. The sulcus transversus of Ecker (S.T.) is present, but behind it there is another and larger transverse sulcus, which communicates below with the former, and which I am strongly convinced represents a persistent condition of the fissura perpendicularis externa, or in other words, of the "Affenspalte."

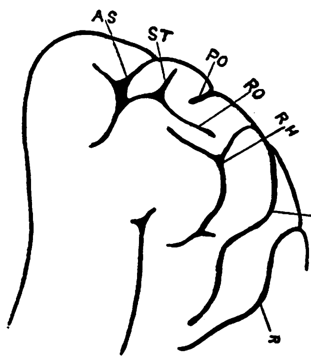

FIG. 9.—Right hemisphere of new-born child. R, fissure of Rolando; P.C, post-central sulcus; R.H, ramus horizontalis of the intraparietal fissure; R.O, ramus occipitalis; S.T, sulcus transversus occipitalis of Ecker; A.S, Affenspalte.

This is not the place to discuss Wernicke's[1] views regarding the "Affenspalte" (his "vordere Occipitalfurche"), but I may be allowed to say that the fissure in the human brain, which he considers to be its representative, lies in a position which puts it out of the question altogether. As the views of this author, however, have received some acceptance, it will be necessary to come back upon this point on a future occasion.

For a time I was inclined to regard the fissure which I have named the external calcarine as the same as the fissura perpendicularis externa, but its position and direction are such

[1] "Das Urwindungssystem des Menschlichen Gehirns," *Archiv für Psychiatrie*, Band vi. Heft 1, 1875.

that I now consider it necessary to look upon it as a distinct fissure. It is placed very obliquely along the lower border of the occipital part of the cerebrum (fig. 10, No. 1), and corresponds on the outer surface of the hemisphere with the calcarine fissure on the mesial face. When transverse sections are made through the occipital part of the cerebral hemisphere, the external calcarine fissure is seen to be a deep infolding of the hemisphere wall, and the bulging which it forms into the ventricular cavity lies exactly opposite, and may be actually in contact with the calcar avis (fig. 10, Nos. 2, 3, and 4).

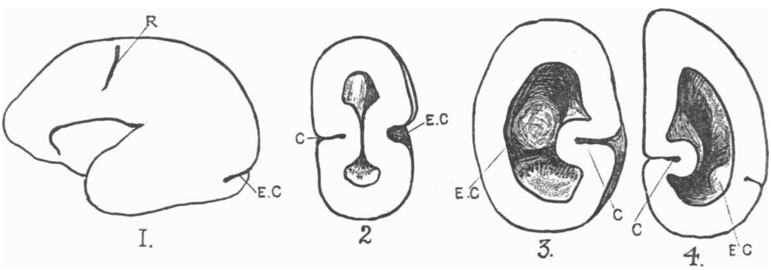

FIG. 10.—No. 1, left hemisphere of fifth month fœtus: R, fissure of Rolando; E.C, external calcarine. No. 2, coronal section through the occipital region of the same hemisphere; C, calcarine fissure; E.C, external calcarine. Nos. 3 and 4, coronal sections through the two hemispheres of a fifth month fœtus. Lettering the same as in No. 2.

The external calcarine fissure appears very early. It can be distinguished in a large number of cases amongst the primitive transitory furrows (figs. 2, 4, and 5, E.C.), and at this period, as we have already noticed, it is frequently continuous around the occipital pole of the hemisphere with the precursor of the true calcarine fissure. This connection, where it exists, is always obliterated about the fourth month. In the human brain the external fissure is transitory. It is effaced about the sixth month. It is a much more constant fissure than the external perpendicular of Bischoff, although in certain cases it also fails completely.

Although evanescent in the brain of Man, there is strong reason to believe that it has a permanent representative in the brain of the Ape. On the outer surface of the occipital lobe of most Apes a deep fissure runs horizontally forwards and comes to an end a short distance behind the free anterior lip of the operculum. This fissure is placed on the outer face of the hemisphere in an exactly corresponding position to the calcarine fissure on the mesial face, but it is shorter than the calcarine fissure, and its anterior end, in most of the numerous specimens I have examined, just falls short of the posterior horn of the lateral ventricle. In two species, however, both of which belonged to the genus Cercopithecus, the fissure in question reached as far forwards as the posterior part of the ventricular cavity, and formed a slight bulging on the outer ventricular wall opposite to the calcar avis on the inner wall (fig. 11). The second occipital

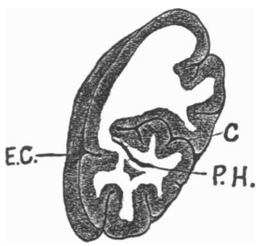

FIG. 11.—Coronal section through the occipital region of the hemisphere of a Cercopithecine Ape. E.C, external calcarine fissure; C, calcarine fissure; P.H., posterior horn of lateral ventricle.

sulcus in the human brain apparently corresponds with this fissure in the cerebrum of the Ape—at least it corresponds to it in position, but not exactly in history, although it is quite reasonable to suppose that the external calcarine is the precursor of the second occipital fissure in Man, in the same way that the true calcarine fissure itself is sometimes preceded by a temporary precursor.

Whilst in the description of these two transitory fissures on the outer aspect of the occipital lobe of the fœtal brain I have inclined to the view that they are to be regarded as distinct fissural integers, I am not blinded to the fact that it is possible that we may really be dealing with one and the same fissure, which alters slightly in position according to the kind of growth-restraint which is put upon the brain. Until they are both seen together on the same hemisphere, this question cannot be definitely settled; but, at the same time, in support of the view that they are distinct and separate, I might call attention to the following points:—(1) The fissures in the Ape, which I believe they represent (viz., the *bottom* of the "Affenspalte" and the external calcarine), are in very close proximity to each other when we completely remove the operculum. (2) There is grave reason to suppose that the "Affenspalte," except in exceptional cases, is not permanently represented in the human brain. This would account for the rare occasions in which the external perpendicular appears even in a transitory state in the human fœtus. (3) If we regard the external calcarine as the precursor of the second occipital furrow, we have an explanation of the greater frequency of its appearance in a transitory form in the fœtal brain.

Relation of the Appearance and Obliteration of the Transitory Fissures to the Growth of the Cerebral Hemispheres and the Mapping-out of an Occipital Lobe.—The transitory infoldings of the early hemisphere wall play an important part in the general growth of the cerebrum, and in the appearance of an occipital lobe. When we read the accounts which are given of the formation of the occipital lobe, an impression is conveyed to the mind that this part of the cerebrum is a local outgrowth or bud which grows backwards from the hinder and upper part of the hemisphere about the beginning of the fourth month; in other words, that it is a secondary formation.

Such is the view which is advanced by Schwalbe, and it may be regarded as giving expression to the opinion which is held by many anatomists on this question. He says:—"We have to separate on developmental grounds the annular lobes (ringförmiger Lappen) from the occipital lobes, which have a *secondary* origin, and which are only present in characteristic development in Man and the Apes."[1]

According to Ecker,[2] the occipital lobe does not exist in the third month; they only appear in the fourth month. He applies the term "Aussackung," or pouching out, to the process of formation. Pansch[3] speaks of the occipital lobe as a hinder "Auswuchs," which, taken along with the context, clearly shows that he regarded the production of the occipital lobe as due to local growth restricted to the hinder end of the hemisphere. Mihalkovics[4] calls the occipital lobe a "Nebenfortsatz," or accessory projection, and frequently refers to the early condition of the hemisphere in which, as he remarks, it only

[1] *Lehrbuch der Neurologie*, Erlangen, 1881, p. 534.

[2] *Archiv f. Anthropologie*, Dritter Band, 1869, p. 208.

[3] *Ibid.*, p. 232.

[4] *Entwicklungsgeschichte des Gehirns*, 1887, p. 111.

consists of a frontal, temporal, and parietal lobe. Krause[1] applies the term "secundärer Auswuchs" and "secundärer Bildung" to it; and Richter,[2] who, as we have seen, admits the very early appearance of the calcarine and parieto-occipital fissures, nevertheless speaks as if he regarded the budding-out of the occipital lobe to be a process analogous to the outgrowth of the optic vesicle.

But, whilst the majority of anatomists would appear to take this view of the formation of the occipital lobe, there are two who have expressed themselves in very different terms. I refer to v. Kölliker and to His. The opinion which v. Kölliker[3] holds regarding the origin of the calcarine and parieto-occipital fissures necessarily entails, as a part of it, the existence from a very early period of a portion of the brain which corresponds to an occipital lobe. His[4] gives an admirable account of the mode in which the occipital lobe is moulded into shape. He explains that it owes its existence to the strong development of the "Brückenkrummung," which, in the primate brain, carries the cerebellum and pons downwards and forwards. His whole description shows that he regards the appearance of the occipital lobe as being due to a general, and not to a local growth.

There are many points which indicate in the clearest manner that the occipital lobe is not a local secondary outgrowth which has sprouted out from the hinder end of the cerebral hemisphere in a bud-like fashion. From the end of the second to about the beginning of the fourth month the young embryonic human cerebrum presents the characteristic bean-shaped outline which has led German authors to apply to it the term "ringförmer Lappen." At this stage the primate cerebral hemisphere resembles in outline the adult condition of the hemisphere in most quadrupeds. A further similarity may be noted in the fact that the Sylvian fissure in the quadrupedal brain stands upright and nearly vertical, and thus corresponds with the vertical direction of the Sylvian fossa in the fœtal primate cerebrum. But as the occipital lobe in the latter takes form, the Sylvian fossa becomes more and more oblique, which clearly shows that the growth is not restricted to the hinder end of the hemisphere, but affects it from one end to the other—in other words, that it is interstitial and general.

The shape of the occipital part of the cerebrum depends upon the restricted space it is called upon to occupy above the cere-

[1] *Handbuch der menschlichen Anatomie*, Zweiter Band, 1879, pp. 728, 729.
[2] *Archiv f. Path. Anat.*, Virchow, 1887, p. 421.
[3] *Entwicklungsgeschichte des Menschen und der höheren Thiere*, 1879.
[4] *Unsere Körperform*, 1875, Neunter Brief, p. 115.

bellum. As it is pushed backwards by the general cerebral growth it is moulded into shape by its surroundings, and its very existence depends, as His has pointed out, upon the strong "Brückenkrummung" of the embryonic primate brain. This backward thrusting also of the posterior part of the hemisphere is chiefly instrumental in preserving the precursory calcarine and parieto-occipital fissures, or causing their reappearance should they have previously become obliterated. The infoldings on the outer aspect of the occipital lobe (external calcarine and external perpendicular) owe their origin to the same influence. But the outer wall of the hemisphere is less hemmed in than the mesial, and consequently there is greater reason for the external infoldings being temporary and less constant than the internal or mesial. Further, those cases which I have mentioned, in which the parieto-occipital fissure traverses the entire depth of the mesial and tentorial aspects of the cerebrum, are explained.

The transitory fissures on the outer surface of the cerebral hemisphere make their appearance, as we have noted, about the beginning of the third month, and undergo obliteration towards the end of the fourth month, viz., at the time when the occipital lobe becomes clearly mapped out as a distinct portion of the cerebrum. This is a circumstance which is deeply suggestive and significant. The majority of observers who have studied the transitory fissures are agreed in ascribing their formation to a more rapid growth of the hemisphere wall than of the skull-capsule within which it is enclosed. The necessary result of such a growth-restraint is, that the thin wall of the hemisphere becomes folded along lines which run at right angles to the axis of growth-energy. But no one has attempted to explain why, at this period, the growth-rate of the skull-capsule and of the contained cerebrum should be at variance with each other. We may, I think, take for granted that the cerebral infoldings occur only in the embryonic brain of primates. Schmidt failed to observe them in Sheep, Oxen, or Pigs, although he thought he saw weak traces of them in the embryo of the Cat.[1] This latter statement I cannot verify. Although

[1] "Beiträge zur Entwicklungsgeschichte des Gehirns," *Zeitsch. f. Wiss. Zool.*, Bd. xi. 1862.

I have looked for the transitory fissures in Cat and Dog embryos of different stages, I have never seen any infolding of the cerebral wall that could be compared with those we have described in connection with the human brain. It is clearly a question which requires further investigation.

The temporary fissures, therefore, are in all probability peculiar to the primates; they occur at a stage of growth prior to the appearance of a well-marked occipital lobe; the great majority of them are effaced when this portion of the cerebrum is moulded into shape; and, lastly, their formation appears to be due to a want of harmony between the growth-rate of the cerebrum and of the skull-capsule. How can these facts be explained?

We may assume that, although cranial and brain-growth, as a rule, go on smoothly and evenly and in perfect harmony with each other, all steps towards an advance of development must be initiated within the brain, and that, for a time at least, the enclosing skull-capsule will resist these. This being granted, we can readily understand that the tendency towards the cerebral growth which gives rise to a well-mapped out occipital lobe is more firmly impressed upon the brain than upon the skull. When the primate head reaches in its development the quadrupedal stage, the cerebrum goes on, without any intermission in its growth, towards the higher development and the formation of a distinct occipital lobe. The cranium, however, pauses in its growth. But this quadrupedal pause marks only a stage in its evolution; it is merely temporary, although it is of sufficient duration to produce the infoldings of the cerebral wall.

But against this view it may be argued that the temporary fissures appear before the third month on the mesial face of the hemisphere. It must be remembered, however, the conditions of growth on the mesial face are different from those on the outer surface of the hemisphere. In the first place, the inner wall is distinctly thinner than the outer wall; and, as His has pointed out,

"through the hemispheres being opposed to each other in the mesial plane, and the space thus restricted, they exercise an influence on each other. Instead of being able by bulging to push themselves out, they are required to adapt themselves to the even and plain bounding surface." [1]

[1] *Unsere Körperform*, Neunter Brief, p. 112.

I have already referred (page 326) to the preservation of the temporary fissures on the outer surface of a brain described by Dr Hans Virchow. I have reproduced a tracing from the photograph which the author gives of this brain, and it is a matter of extreme interest to observe that the cerebrum presents an outline similar to that of a brain between the third and fourth months of intra-uterine life. The growth which would have led to the mapping out of a distinct occipital lobe has been arrested, and, consequently, the temporary fissures have been retained. The general similarity in outline to that of a quadrupedal brain is very marked.

Further evidence in support of the view which I have advanced might be adduced from the fact that variations in the capacity of the hinder part of the cranium are much greater than those in the fore part.[1]

Considering, then, that the occipital lobe in primates owes its origin to a general growth of the cerebral hemisphere, and not to the sprouting out of a local bud from its hinder end, it would be wrong to deny the presence of a corresponding portion of the cerebrum in the lower mammals. From this point of view, Benedikt[2] has some ground for his assertion that in the mammalia generally there is an occipital lobe. Upon his further statement that the calcarine fissure is also developed in brains below the primates we are not in a position at present to offer an opinion.

With the expansion of the cranial cavity the temporary fissures become obliterated by the partial opening out of the infoldings. The cerebrum at the same time increases in length and the occipital lobe comes clearly into view. But the increase in length is not so great as that which would be produced by the complete opening out of all the transitory infoldings of the cerebral wall. This can readily be proved by measuring the depth of the fissures and calculating the increase in length which the cerebrum has undergone between the time when these fissures were present and the period when it is entirely smooth. The question, therefore, comes to be—What becomes

[1] Virchow's *Gesammelte Abhandlungen zur wissenschaftlichen Medicin*, 1856.

[2] *Der Hinterhaupts-Lappen der Säugethiëre*, von Dr Moritz Benedikt (Wien). Sep. Abdr. a. d., *Centralbl. f. d. Med. Wissensch.*, 1877, No. 10.

of the deeper parts of the folds? To this, I suspect, we cannot offer a satisfactory answer. We have seen that Meckel, the original observer of these transitory fissures, was of opinion that their obliteration was due to the growing together of their opposed surfaces. Certain it is that the deepest part of the bottom of the infolding cannot reach the surface of the brain in every case unless it does so by a partial absorption of the walls of the fold. This, combined with the partial opening out of the fissures, may serve to account for their disappearance. Further research, however, is required in connection with this part of the inquiry, and this can only be conducted by one who has a large amount of particularly well-preserved material at his disposal.

Richter has advanced the theory that the choroid plexuses, as they expand in size, may have some influence in bringing about the unfolding of the temporary fissures, and in smoothing out the surface of the cerebral hemisphere.

In the course of my examination of the beautiful series of specimens in the museum of the University College, London, I met with a very remarkable deformity in the posterior part of the right cerebrum of a fœtus between the third and fourth

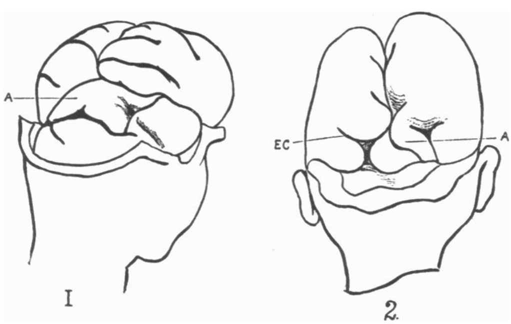

FIG. 12.

month. A hollow outgrowth projected backwards over the mesencephalon, upon the upper surface of which it was closely adapted. It was spread out, so as to cross the mesial plane, and its posterior border showed an angular deficiency which gave it a forked appearance (fig. 12, No. 1). The under wall of this outgrowth or lappet was formed of an epithelial layer only.

Its precise attachment to the cerebrum could not be made out without destroying the specimen, but it appeared to be attached by a stalk to the under and back part of the cerebrum. The posterior part of the temporo-sphenoidal lobe, which was completely separated from the remainder of the cerebrum by a deep temporary fissure, overlapped this stalk and hid its connections.

It is difficult to imagine what the further history of such an embryo would have been had it survived. The deformity cannot be very rare, as Richter has figured a specimen which shows a very similar condition (fig. 12, No. 2).